An olympic legacy: Green and golden bell frog conservation at Sydney Olympic Park 1993-2006

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ABSTRACT

The Green and Golden Bell Frog *Litoria aurea* population at Sydney Olympic Park is one of the largest populations of the species remaining in New South Wales. This endangered species was identified in the midst of extensive site development occurring for the 2000 Sydney Olympic Games, and became the focus of a long-term conservation program that has significantly influenced the design and development of the Park. This program has resulted in conservation of the original population, and establishment of two new self-sustaining sub-populations on newly-built habitats on remediated lands.

This paper presents an overview of the frog conservation and management program at Sydney Olympic Park from 1993 to 2006. It describes how legislation, science, policy, development and sport have, with the dedication of hundreds of people and the tenacity of the frog itself, come together to bring about the frog's conservation. It describes how the frog and its habitat continue to be managed in an urban parkland setting, and the future challenges that are present in securing the long-term viability of the population.

Key words: Green and Golden Bell Frog, *Litoria aurea,* Sydney Olympic Park, Homebush, habitat restoration

Introduction

The Green and Golden Bell Frog *Litoria aurea* occurs from northern New South Wales (NSW) to north-eastern Victoria, mainly in the coastal zone but with the range extending west in the Hunter and onto the central and southern tablelands (White and Pyke 1996, 1999; Pyke and White 2001). The species underwent a major decline in abundance from the 1970s to the early 1990s (White and Pyke 1996) and became listed as an endangered species in 1991 under New South Wales legislation (*Endangered Species (Interim Protection) Act* 1991).

A review of the known locations in Sydney and elsewhere in NSW suggested that a population at Homebush Bay (now Sydney Olympic Park) was significant at the state level (Greer 1994; White and Pyke 1996). This led to the species becoming a central component of the environmental planning for Sydney Olympic Park as it was developed for the 2000 Sydney Olympic Games. This paper describes the integration of frog conservation with the planning process for the remediation and redevelopment of Sydney Olympic Park.

Before redevelopment – frog habitats in 1993

The Green and Golden Bell Frog was first confirmed within the area now known as Sydney Olympic Park in 1992 (Greer 1994). Most of this land had been under State or Federal Government control since the early 1900s when two large agricultural estates, 'Newington' and 'Home Bush', were returned to government ownership. Through the 1900s, the land was developed for various government-owned industries including the State Brickworks, State Abattoir, and Royal Australian Navy Armament Depot, and there was landfilling of an estimated 9 million cubic metres of domestic, commercial and industrial waste. As the industries began to close in the 1980s, nearly 800 ha of land in the geographic centre of Sydney and 14 km from the city centre became available for urban renewal. Early redevelopment plans included two options, depending upon whether or not Sydney was chosen to host the 2000 Summer Olympic Games.

The area was anecdotally regarded as having high ecological values despite a history of habitat alteration and industrial use, and its ecological isolation in urban surrounds (Greer 1994). Species and communities considered to be of local and regional conservation significance included large stands of coastal saltmarsh, remnant Sydney Turpentine-Ironbark Forest, migratory shorebirds, mangrove forest, a high diversity of native birds, bats and fish, and the Green and Golden Bell Frog. The Homebush Bay Corporation (the state government agency then responsible for the land) sought to integrate ecological conservation with site redevelopment, and to assist this goal they established an expert review panel of professional ecologists and environmental scientists, and commissioned a suite of ecological studies to provide baseline information on the site's flora and fauna (OCA 1995).

With the Games potentially only seven years away, planning, remediation and redevelopment was occurring concurrently with these studies. The 16-ha quarry of the former State Brickworks (the Brickpit) had been chosen as the venue of the Olympic Tennis Centre. Under this proposal, the Brickpit was to be partially filled with solid waste, and a 17-court tennis complex, amphitheatre and water feature built within it.

The Brickpit had been developing naturally into a freshwater wetland since quarrying for shale stopped in 1988 (quarrying of sandstone bedrock continued in the northern section of the pit until 1992). New Brickpit habitats included water-bodies of varying sizes and degrees of permanence, scattered piles of quarrying debris, rubble dumped after demolition of the adjacent abattoir, and colonising trees, shrubs, grasses and reeds. Targeted surveys conducted between May and December 1993 identified Green and Golden Bell Frogs (hereafter bell frogs) and tadpoles across all levels of the Brickpit. The population was conservatively estimated at 55-110 adult frogs (based on techniques described by Greer 1994), and was considered to be the largest and most viable known population within the Sydney region (Greer 1994).

Surveys also identified bell frogs and tadpoles outside the Brickpit (Fig. 1). These highly disturbed lands contained little remnant vegetation; dominant habitats were mown and unmown grasslands, swampy landfills, low-lying depressions that functioned as ephemeral ponds, and more permanent waterbodies constructed for stormwater and abattoir wastewater management. Small areas of remnant estuarine and forest vegetation also remained. Habitats were on open lands surrounding and interwoven with buildings, roads, carparks, and areas undergoing extensive earthworks for remediation. Surveys in 1993 located mainly individual frogs in small and scattered pockets of habitat, many of which were intended for development; tadpoles were found at three locations. From these surveys, the bell frog population outside the Brickpit was conservatively estimated at 50-100 adult frogs (Greer 1994). Ecologists considered the Brickpit to be core habitat for a self-sustaining bell frog population, with populations in the surrounding area probably maintained by emigration from the Brickpit during periods of suitably wet weather (Greer 1994, Pyke 1995). Criteria used in defining a self-sustaining population (NPWS 1995) were:

- 'breeding is observed whenever conditions are suitable
- there is a reasonable frequency of breeding
- there is a reasonable degree of success for breeding attempts, and
- *there is a regular presence of the species at or near the site.'*

Integrating frog conservation and site development: 1994-2000

The International Olympic Committee announced that Sydney had won the right to host the 2000 Summer Olympic Games in September 1993, giving only seven years to remediate the site and construct the Games venues and infrastructure. The urban renewal program was fast-tracked to meet this deadline and an intensive site development program began.

Because the bell frog was listed as 'endangered' under Schedule 12 of the *NSW National Parks and Wildlife Act* 1974 (NPW Act) there were several regulatory requirements that had to be met prior to further development. These included a Licence to 'take or kill' any frogs harmed in the course of site development (*NSW National Parks and Wildlife Act* 1974), and, for development applications lodged under the *NSW Environmental Planning and Assessment Act* 1979, preparation of a Fauna Impact Statement (*NSW Endangered Fauna (Interim Protection) Act* 1991). Following commencement of the *Threatened Species Conservation Act* 1995, such Licence or development applications required completion of an 8-part test, and potentially a 'Species Impact Statement', as detailed in the Act.

Licensing for development of the Brickpit

In January 1994, the Homebush Bay Corporation sought a Licence to 'take or kill' bell frogs for redevelopment of the Brickpit. The proposal involved destruction of all Brickpit habitat and a commitment to modify four widely-spaced water quality ponds built outside the Brickpit to provide frog habitats. If necessary, new ponds would continue to be built until the frog population outside the Brickpit exceeded the estimated population size within the Brickpit.

The Fauna Impact Statement (Greer 1994) identified that the Brickpit bell frog population was likely to be the largest in the Sydney region, and that its loss without replacement could be significant to the long-term future of the species across the region. It identified that the Brickpit was likely to be very important through emigration in maintaining the size and genetic diversity of the smaller populations occurring on surrounding lands, and concluded that the most certain way to protect the frog was to *'leave the Brickpit alone, or better, to enhance its wetland habitat values'*. It described development of replacement habitat as the next-best option, and discussed the measures proposed.

The Licence application in its original form was rejected by the regulatory authority (NSW National Parks and Wildlife Service). Reasons included the high conservation significance of the Brickpit population, the lack of scientific knowledge of the species' ecology, uncertainty over the likely success of the new habitats, and uncertainty of the future land use context and security of the new habitats. Because of the high conservation status of the population, it was considered that any development should not compromise the local or regional viability of the species (NPWS 1994). Instead a Licence (TS0076) valid for 10 years was issued in November 1994 that set out a strategy for identifying and protecting core Brickpit habitats, with development in non-core areas to be reconsidered when more information about the frog became available. With the Games deadline approaching, a new location was chosen for the Olympic tennis centre.

Licensing for developments outside the Brickpit

Plans for future land use outside the Brickpit were being developed while the decision over the Brickpit Licence was pending. Masterplanning had divided the site into seven precincts (Homebush Bay Corporation 1994). Implementation of the Masterplan would destroy and/or disrupt much of the existing ephemeral bell frog habitat

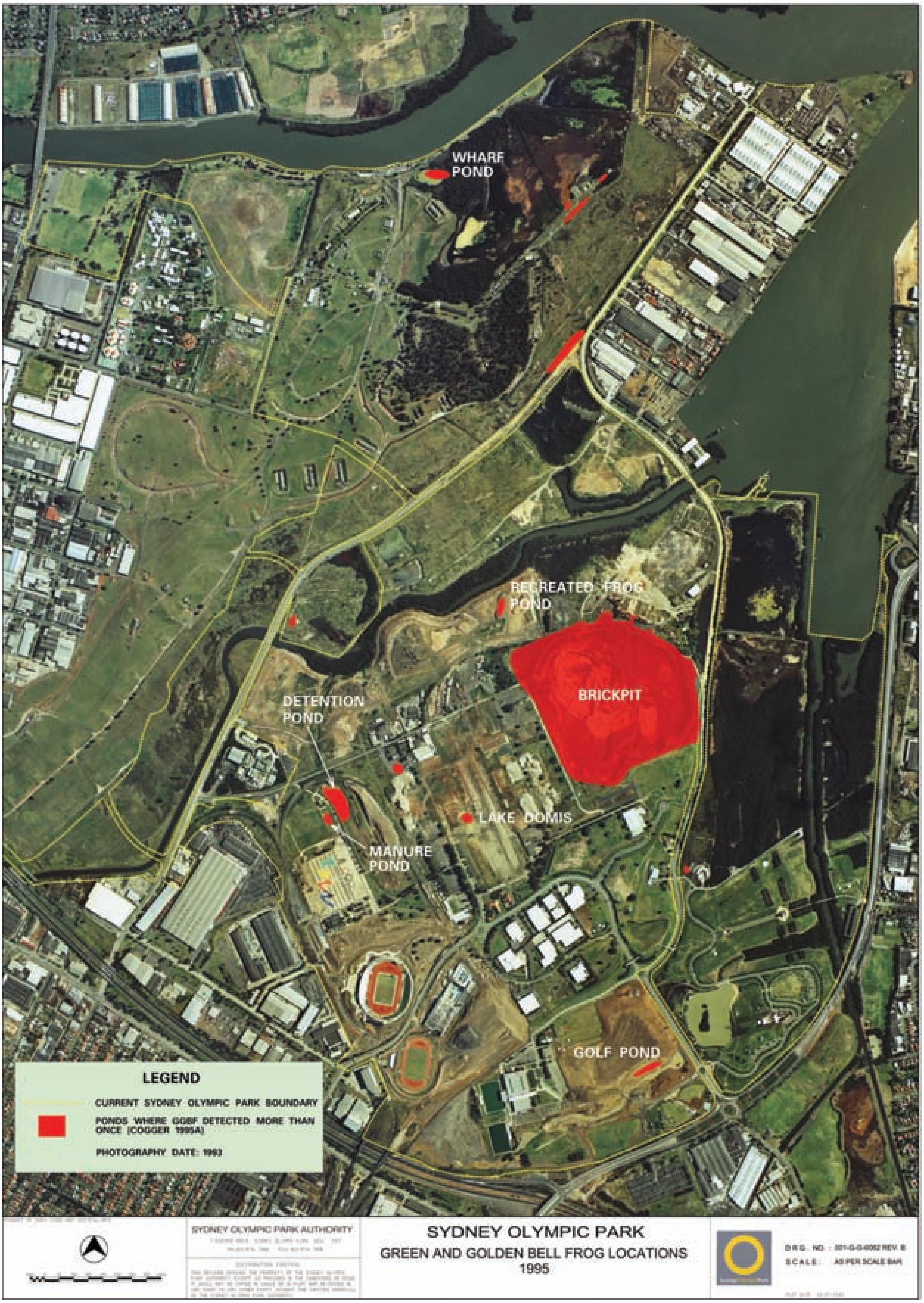
WHARF POND
RECREATED FROG POND
BRICKPIT
DETENTION POND
LAKE DOMIS
MANURE POND
GOLF POND
LEGEND
CURRENT SYDNEY OLYMPIC PARK BOUNDARY
PONDS WHERE GGBF DETECTED MORE THAN ONCE (COGGER 1995A)
PHOTOGRAPHY DATE: 1993
SYDNEY OLYMPIC PARK AUTHORITY
SYDNEY OLYMPIC PARK
GREEN AND GOLDEN BELL FROG LOCATIONS
1995
DRG. NO.: 001-G-G-0062 REV. B
SCALE: AS PER SCALE BAR

Figure 1. Green and Golden Bell Frog habitat locations in 1995.

outside the Brickpit. It would also reduce opportunities for the species to disperse across the landscape, and result in the death of individual frogs.

In June 1995, the Homebush Bay Corporation sought a Licence to 'take or kill' frogs for development described in the 1994 Masterplan. The Fauna Impact Statement (Pyke 1995) proposed extensive mitigation measures that included:

- exclusion of development and associated activities from a buffer zone around the Brickpit
- prevention of surface water flow into the Brickpit from areas of development
- prevention of general public access into the Brickpit
- removal of as many frogs and tadpoles as possible from development areas before development proceeds
- creation of artificial habitat (including approximately 20 ponds in the areas now called Kronos Hill and Wentworth Common)
- construction of underpasses suitable for frog movement under the new roadways
- erection of frog-proof fencing between the Brickpit and any road that ran near its rim.

A 2-year monitoring program was proposed to gauge the success of these measures. The principles to be applied to pond, corridor and underpass construction were described, based on what was known of the species' ecology at the time.

The Faunal Impact Statement identified that under the proposal there would be a reduced distribution and abundance of bell frogs outside the Brickpit. However, because the population in this area did not appear to be self-sustaining, it was considered that the viability of the local bell frog population and the conservation status of the species would not be affected, provided that the Brickpit itself was protected.

A Licence (TS0103) valid for six years was issued in November 1995, permitting destruction of habitats outside the Brickpit. Licence conditions required implementation of the proposed mitigative measures, including construction of the new habitats. The regulatory authority and public submissions noted that these measures were untested, and that the monitoring program was an essential part of the proposal (NPWS 1995). As a result, Licence conditions required monitoring to be conducted for the duration of the Licence, and for performance indicators and contingency measures to be developed.

Development consents for site development

In September 1995, a new Masterplan was issued for the site, which modified or changed many of the developments on which the previous two fauna impact statements had been based. This created new impacts on bell frog ephemeral habitat outside the Brickpit. Three Fauna Impact Statements were prepared (Cogger 1995a, b, c) as part of the development applications lodged for: the new Masterplan, for construction of the showground site, and for construction of roads infrastructure within the Masterplan area. The Fauna Impact Statements concluded that the impacts of the developments on bell frogs would remain largely unchanged from those considered in the original licence applications; compliance with these Licences was subsequently adopted as a consent condition for each development, along with some project-specific conditions.

Proposed remediation works to land north of Haslams Creek (creek located north of the brickpit; Fig. 1) in 1996 triggered a Species Impact Statement under the new *NSW Threatened Species Conservation Act* 1995 (Robertson *et al.* 1996). Habitats here included extensive areas of grassland and freshwater wetlands that had developed following landfilling and artificially impeded drainage. High pollutant levels were recorded in some of these wetlands as a result of ongoing leachate contamination. The bell frog population of the area was estimated at 140 adults, based on surveys reported in Pyke (1995). Proposed works included remediating the land by removing and containing contamination, building the Olympic Village, reconstructing and widening Haslams Creek, and building areas for recreation. A large complex of freshwater ponds was to be constructed to provide replacement habitat for the frog. The Species Impact Statement identified that because of the degraded and polluted state of the existing habitats, the remediation and development proposal would potentially improve the prospects of long-term survival of bell frogs in this area. Development was approved, with development consent conditions including the requirement that the wetlands be adaptively managed such that they '*become a healthy and flourishing habitat for birds, the Green and Golden Bell Frog and other native species*' (Department of Planning 1996 - DA S/38/10/96). The freshwater ponds are now known as Narawang Wetland (Fig. 2).

The Brickpit, new frog habitats, and other open-space areas were included in the newly-defined 'Millennium Parklands' in 1997. The Millennium Parklands Concept Plan (Hassell 1997) provided a vision and 15-year staged development plan for the parklands, to support activities including environmental and heritage conservation; active and passive recreation; heritage interpretation and environmental education; access, parking and internal circulation; public art; ancillary commercial and administrative uses; and temporary uses associated with the Olympic Games. A Frog Management Strategy (OCA 1997) contained ameliorative measures for the proposal, to be met and maintained for the duration of the Plan, to minimise impacts of parklands development on areas identified as the most important bell frog habitat outside the Brickpit (Cogger 1997). This Strategy formed the basis of environmental assessment by the regulatory authority and hence for the development consent that was subsequently issued for development of the Parklands. Consent conditions also required compliance with existing Licence conditions and prohibited all but defined minor work in the Brickpit.

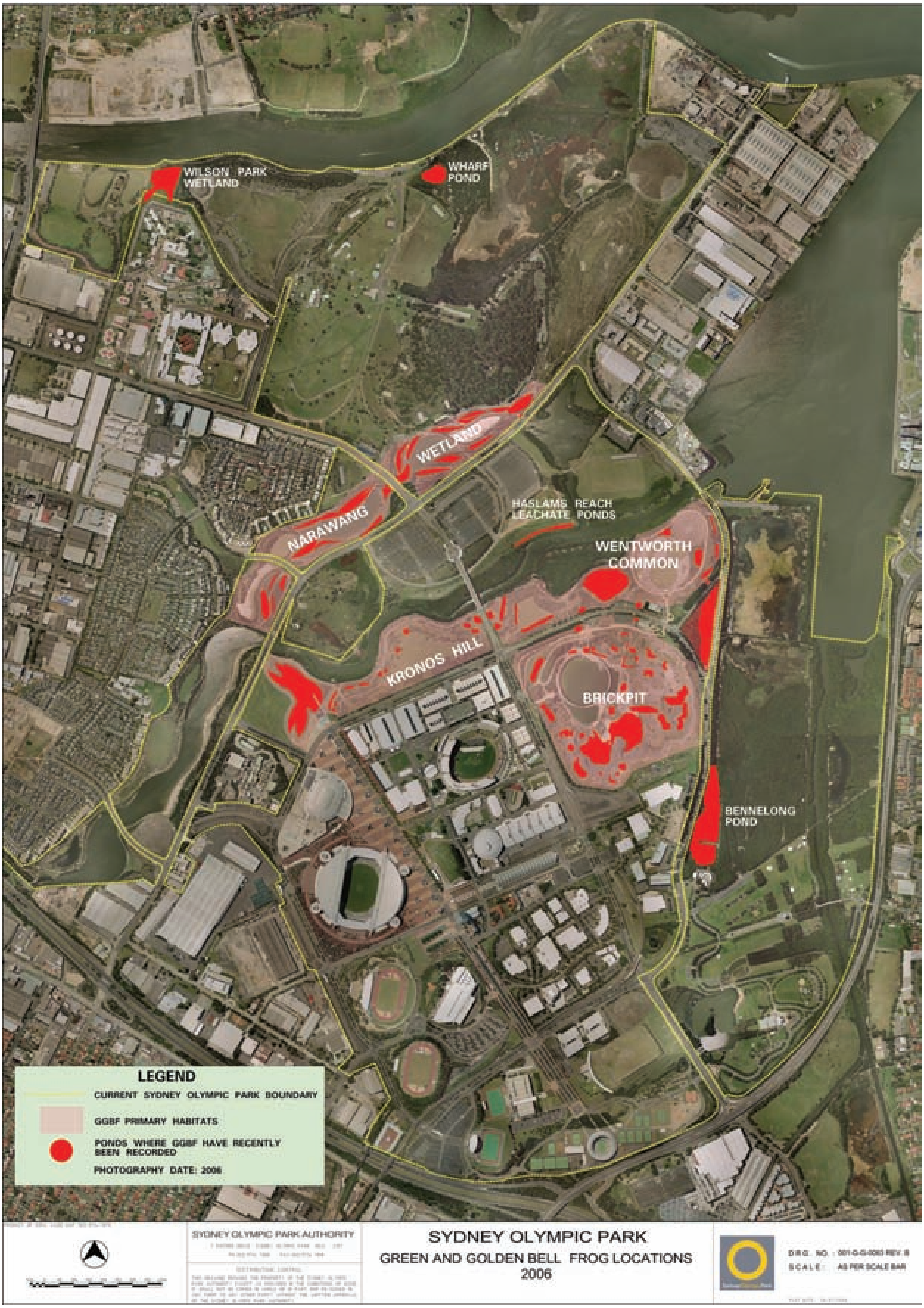
WILSON PARK WETLAND
WHARF POND
WETLAND
NARAWANG
HASLAMS REACH LEACHATE PONDS
WENTWORTH COMMON
KRONOS HILL
BRICKPIT
BENNELONG POND
LEGEND
CURRENT SYDNEY OLYMPIC PARK BOUNDARY
GGBF PRIMARY HABITATS
PONDS WHERE GGBF HAVE RECENTLY BEEN RECORDED
PHOTOGRAPHY DATE: 2006
SYDNEY OLYMPIC PARK AUTHORITY
SYDNEY OLYMPIC PARK
GREEN AND GOLDEN BELL FROG LOCATIONS
2006
DRG. NO.
SCALE: AS PER SCALE BAR

Figure 2. Green and Golden Bell Frog habitat locations in 2006

Other developments in habitats outside the Brickpit also occurred in the lead-up to the Games, including stormwater control ponds, a horse exercise trail, a showground carnival site, and temporary Olympic Overlay works. In total, five fauna impact statements, two species impact statements and approximately twenty 8-part tests were prepared for the bell frog from 1994 to 2000. Many of the development applications and/or consent conditions for these developments included long-term commitments to frog conservation and management, and all development consents required compliance with existing frog Licences.

Frog conservation and habitat construction: 1995-2000

Program strategy

The frog conservation and habitat construction strategy that was followed in the lead-up to the Olympics (Table 1) was strongly based on the Licence conditions, the commitments made in development applications for the various construction projects, and subsequent development consent conditions. Together the two Licences set out conditions that aimed to ensure there was no long-term decline in the frog population at the site - while the total area of ephemeral habitat available to the frog would be reduced by development, its core habitat in the Brickpit would be maintained intact (Cogger 1995b). Frogs located in the path of proposed developments would be removed and relocated to newly constructed habitats on remediated lands. The Brickpit habitats would only be developed after reproducing frog populations were established in new habitats built on newly-remediated lands.

Cogger (1995b) concluded that

> '*all available evidence suggested that the L. aurea population is*
>
> - isolated from other populations within the Sydney region, and
> - self-sustaining only if the reproducing population occupying the Brickpit is maintained
>
> *… conservation of the population ultimately depends on either maintaining and conserving existing frog habitat in the Brickpit, or creating new, rehabilitated habitat elsewhere … that could be shown to maintain population levels and reproductive rates equivalent to or greater than those currently maintained in the Brickpit*'.

Implementation of the Licence conditions and development consent conditions would conserve the population at a local level, thus avoiding any significant impact on the regional or statewide conservation status of the species.

Frog management plans were prepared as development progressed (AMBS 1996; Norman *et al.* 1998; Muir *et al.* 1999a), and were approved by the regulatory authority. These plans integrated Licence conditions and the recommendations from fauna and species impact statements, and provided the guiding strategy for frog conservation and habitat construction throughout site development. Design and construction of the new habitats

Table 1. Summary of Green and Golden Bell Frog conservation actions at Sydney Olympic Park 1994-2000.

Actions inside the Brickpit	Actions Outside the Brickpit
Initially quarantined from all development, pending further ecological investigations and regulatory approvals • Fenced to exclude public access. • Protected from impacts of development on adjacent lands, including stormwater run-off and lightspill.	Habitat constructed on newly-remediated lands, initially to mitigate against loss of ephemeral habitat, later expanded in scope to support long-term viability of the population.
Ecological investigations of Brickpit habitats to better understand frog habitat requirements and their locations in the Brickpit. Funding of a PhD study of bell frog ecology.	Frogs in ephemeral habitats relocated prior to development works.
Testing of frog habitat creation outside the Brickpit.	Habitat built to support self-sustaining satellite frog populations in two areas – Kronos Hill / Wentworth Common, and Narawang Wetland: 29 constructed ponds in grassland setting in Kronos Hill / Wentworth Common spread over 40 ha Frog habitat features incorporated into large wetlands that formed part of the stormwater management system 11 road underpasses built to link frog habitat areas 6 km of permanent frog fencing installed.
In 2000, destruction of some core Brickpit habitats, mitigated by construction of replacement habitat within the Brickpit and progressive enhancement of low-value Brickpit habitats	Supplementary terrestrial and aquatic habitat in other areas.
Frog Management Plan prepared and implemented	Frog Management Plan prepared and implemented .
6. Monitoring and reporting.	Monitoring and reporting.

involved a multidisciplinary team of herpetologists, engineers, planners and landscape architects. A scientific review committee was established to provide expert ecological input to the process.

Olympic environmental framework

Frog conservation works benefited from the environmental initiatives that applied to all of Sydney's Olympic Games developments. Sydney's bid for the Games included a set of Environmental Guidelines for implementation by host cities (Sydney 2000 Bid Limited 1993). These were based on sustainability principles adopted at the 1992 United Nations Earth Summit, and contained commitments to the preservation and protection of natural ecosystems and endangered species, energy and water conservation, waste minimisation, and air, water and soil quality.

When the Olympic Co-ordination Authority took over management responsibility for the site in 1995, The *Olympic Co-ordination Authority Act* 1995 and the *State Environmental Planning Policy* 38 (SEPP 38) required the Environmental Guidelines to be applied to all Olympic developments. Companies tendering for construction contracts were required to demonstrate how they would satisfy the Environmental Guidelines (OCA 1996). Environmental management plans addressing the guidelines were prepared for all design and construction projects. Environmental training was provided to staff and construction contractors (OCA 2000), and performance was regularly audited by independent environmental watchdogs (Greenpeace 2000; Earth Council 2001). Conservation of the bell frog was integrated into all of these processes.

Habitat construction in Kronos Hill / Wentworth Common

Construction of frog habitat outside the Brickpit began in 1995 in the areas now known as Kronos Hill and Wentworth Common. The designs of ponds, movement corridors and underpasses were initially based on guidelines contained in Pyke (1995). The first ponds were seven redundant sediment control ponds created during previous earthworks, which were planted with macrophytes to provide frog habitat. These were shortly followed by 13 purpose-built ponds (Fig. 3). Native grasslands and rockpiles were established around and between the ponds. Ponds were rapidly colonised by frogs soon after construction, and frogs were also translocated to them from ephemeral habitat on development sites.

Efforts to establish these frog habitats were occurring concurrently with further development of the area, and over the next five years several recently-built successful ponds were removed and new ponds were built nearby to accommodate roads, stormwater treatment ponds, pathways and landforms not originally envisaged (Muir *et al.* 1999b). New ponds were also built to replace ponds that developed leaks – thought to be due to settling of the landfill containment mound upon which they were built.

The frog conservation strategy evolved as research and monitoring data became available and site development requirements shifted. By early 1998, the long-term conservation of the frog population at the site was to be achieved by establishing a viable metapopulation in habitats located both within and outside the Brickit (Norman *et al.* 1998b). Previously, habitats outside the Brickpit had been intended to offset the loss of ephemeral habitats and to 'duplicate' the Brickpit population so that the Brickpit could eventually (with further approvals) be developed.

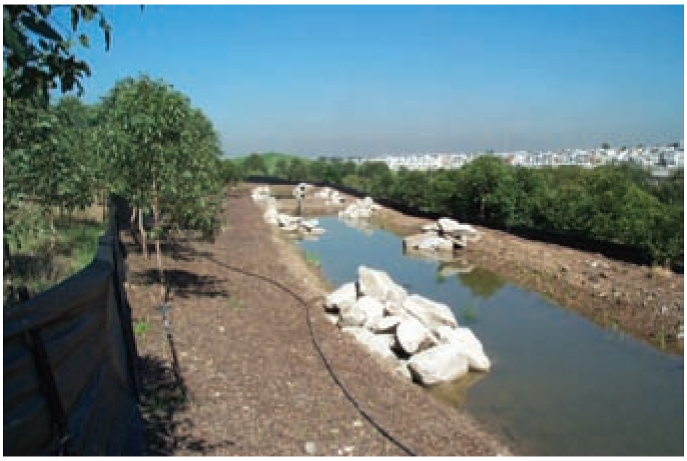

Figure 3. Constructed frog pond at Kronos Hill

Two options were canvassed (AMBS 1997):

1. Partial development of the Brickpit and construction of replacement habitat within the Brickpit. Development of the entire Wentworth Common and Triangle Pond area as frog habitat.
2. Partial development of the Brickpit and construction of replacement habitat within the Brickpit. Development of several 'satellite' habitats with shared land uses in what is now the Kronos Hill, Wentworth Common, Narawang Wetland, and Bicentennial Park precincts, linked by movement corridors.

Option 1 was preferred in terms of conservation value. Wentworth Common had originally been identified as the site of the Olympic archery centre but became available for other uses when this venue was relocated. The only constructed frog breeding habitat that had proven successful over several years was located in this area. It was large enough to consolidate and extend the frog habitat elements needed to support a self-sustaining frog population, and it was located adjacent to both the Brickpit and Bicentennial Park, facilitating frog dispersion and genetic exchange between these habitats. As a purpose-designed frog habitat, it could be 'priority managed' for frog conservation; an added advantage was that other lands could be 'freed' of frog constraints in balancing land uses. Creation of an 'environmental park' such as this was originally considered in the determination of the Brickpit licence application (NPWS 1994) – it was then suggested that such an area would need to be similar in size to the Brickpit, not impacted by developments in the long or short-term, free of roads and pollution, with numerous wetlands, and with limited public access.

Option 2 was the strategy that was ultimately pursued, because many of the features that made Wentworth

Common ideal for frog habitat development also suited other land uses. Wentworth Common was subsequently developed as a recreational space, with frog habitats remaining around the edges.

By 2000, there were 29 constructed ponds in the 40-ha Wentworth Common / Kronos Hill area. The newer ponds were connected to the site's irrigation system; all ponds were later connected enabling pond water levels to be topped up in dry periods. The area contained two large wetlands that formed part of the site's stormwater management system and which supported strong breeding aggregations of the frog (the Eastern Water Quality Control Pond built in 1997 and Northern Water Feature built in 1999) (Muir 1999b; Magarey 2001). Eleven frog underpasses were incorporated into the design of new roads to provide connectivity between the Brickpit and Kronos Hill, Wentworth Common and Bicentennial Park. Six km of frog fencing was installed between roads and habitats.

Habitat construction in Narawang Wetland

The 20-ha Narawang Wetland (Fig. 4) constructed on newly-remediated land north of Haslams Creek was completed in 1999 and 2000, and was rapidly colonised by bell frogs. The wetland contains 22 large clay-based habitat ponds, three irrigation storages and an ornamental lake, and was planted with native reeds, grasses, shrubs and trees. Ponds were connected by a water recirculation system so that individual ponds could be pumped out and dried, and the water recirculated to other ponds.

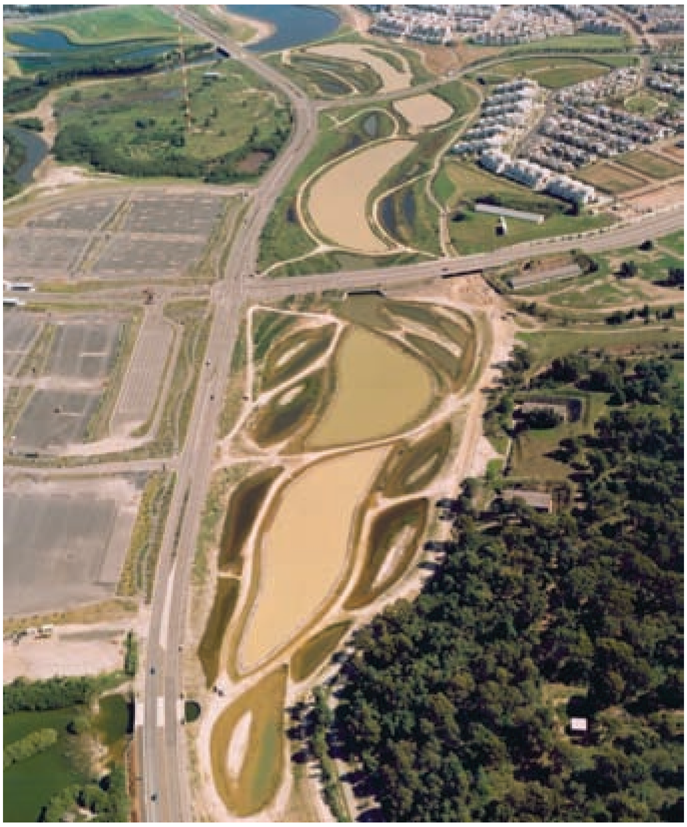

Figure 4. Narawang Wetland in 2000, soon after construction.

The genetic relationship of the frog populations north and south of Haslams Creek was uncertain, because they were seemingly separated from each other by the saline Haslams Creek. The first development consent for the area north of Haslams Creek (Department of Planning 1996 – DA S38/8/96) required installation of a frog-proof boundary fence to separate the northern (Narawang) frogs from the southern (Brickpit, Wentworth Common/Kronos Hill) frogs. However, a genetic study (Colgan 1996) concluded that the genetic distance between the two populations was very low, suggesting recent common ancestry or high migration between sites. Possible migration points were road bridges, the creek itself at times when saline creekwater was diluted by heavy rainfall, and the creekbed where it was reduced to a series of narrow rivulets at low tide during dry periods. Removal of a mangrove choke during remediation works widened the creek, lessening the likelihood of frog dispersal across it. The Narawang sub-population is now even more highly isolated from sub-populations south of Halsams Creek because of the width of the creek, and absence of suitable corridors and road underpasses.

Brickpit development and habitat creation and enhancement: 1999 - 2000

Concurrent with habitat construction works outside the Brickpit, a PhD study of bell frogs within the Brickpit (Christy 2001) and habitat assessment work (Norman *et al.* 1998a) were providing information about the frog's ecology and how it used the various Brickpit habitats. Licence conditions had required this information to be available before any approval was given for development within the Brickpit. The 1994 Decision Report (NPWS 1994) noted that the Brickpit was a man-made structure and also a managed one, with frog habitats on the lower levels only maintained by the pumping out of excess water after heavy rains. Ongoing pro-active management of Brickpit habitats would be required to maintain the viability of the population; a requirement to manage this habitat for bell frog conservation over the long-term would be the trade-off for the regulatory authority allowing partial development of the Brickpit.

In mid-1999 the Olympic Co-ordination Authority lodged a development application for the Water Reclamation and Management Scheme (WRAMS). WRAMS was a major water recycling initiative and an environmental commitment of the Environmental Guidelines for the Olympic bid. It would produce recycled water from harvested stormwater and sewage effluent. Recycled water would be used instead of potable water for toilet flushing in the suburb of Newington, in venues including the olympic stadium, superdome, showground and hotel, and for park irrigation, saving 850 million litres of potable water per year.

The WRAMS required a large water storage reservoir, and it was proposed to site this in the lower two levels of the Brickpit (Levels 2 and 3), giving a storage capacity of 300ML. A Species Impact Statement for the bell frog (Muir *et al.* 1999b) was submitted as part of the development application. The Species Impact Statement identified that Level 2 of the Brickpit was a highly significant habitat area for the bell frog, utilised by 25-30% of the Brickpit's total frog population. It concluded that '*the project will have a significant impact on the frog population, and will permanently remove a significant area of core habitat that (a) currently sustains a large proportion of the Brickpit frog population; and (b) provides breeding sites that lead to a high level of recruitment; the latter is probably significant to the Homebush Bay population as a whole*'.

To ameliorate against this loss, the Olympic Co-ordination Authority proposed substantial frog habitat works as part of the development application:

1. construction of new habitat areas to replace the habitat destroyed, such that the size of the Brickpit population would be maintained similar to pre-development levels,
2. progressive long-term enhancement of parts of the Brickpit considered to have low frog habitat value, in order to increase frog density and breeding in these areas.

Brickpit habitats would only be destroyed after performance criteria were met in the new Brickpit habitats and in constructed habitats outside the Brickpit. The bell frog population outside the Brickpit was at that time centred in the Wentworth Common area – in constructed ponds around its perimeter (the central part of Wentworth Common was then undergoing large-scale earthworks) and in the Eastern Water Quality Control Pond. Large numbers of frogs had been observed in these habitats (Muir *et al.* 1999b), and successful breeding recorded over three successive seasons. There were as yet relatively low frog numbers in other constructed habitats - the Northern Water Feature and the Narawang Wetland were still being built, and many constructed ponds elsewhere at Kronos Hill either required replacement after being removed for development or had developed leaks and needed repair.

Development consent was granted in August 1999, and the initial habitat construction works produced some 19 ponds, 10 soaks, 4000 m^2 of planted grasses and 5000 tonnes of rock piles in works spanning 6 months (Fig. 5). The ponds were rapidly colonised by frogs and breeding was recorded in some within weeks of completion. Five ponds were rebuilt in the Kronos Hill area as part of the works program to provide greater surety for the viability of the frog population outside the Brickpit. A lantana-dominated part of the Brickpit rim was rehabilitated and replanted with native plants, also as part of these works. Following relocation of frogs from the lower levels of the Brickpit, the Reservoir was flooded from May 2000, removing Level 2 habitats.

Frog habitat management during the Olympics: September 2000

By early 2000, most of the constructed ponds, grasslands, fencing and underpasses were in place. The 2000 Summer Olympic Games were held in September 2000, with some 4.47 million visitors attending the site. Some Games-related activities were sited in or adjacent to frog habitat areas, and mitigative measures were incorporated into design, construction, and operational plans of each of these facilities:

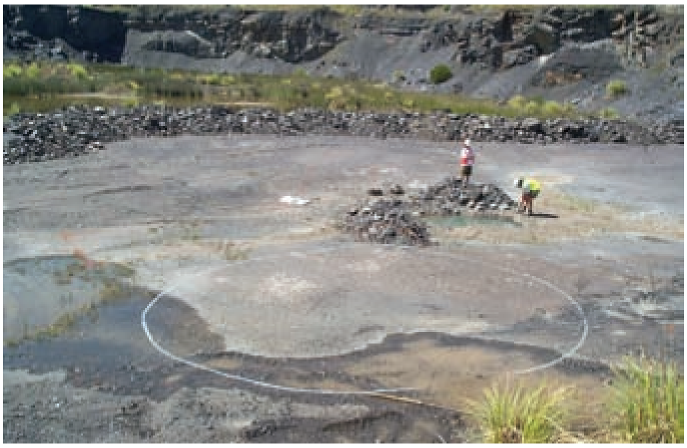

Figure 5. Habitat construction in the Brickpit.

- support facilities for the equestrian component of the Modern Pentathlon were located at Wentworth Common – these included temporary stables, accommodation for grooms, and a competitor training arena. Temporary frog fencing was installed around these facilities to exclude frogs.
- the main pedestrian route between the western bus terminus and the Games venues traversed Kronos Hill – tens of thousands of people crossed this area each day; grassy habitats were fenced to exclude public access, and the route was closed at dusk each night.
- Kronos Hill was also used for staging fireworks displays during the Opening Ceremony and two dress rehearsals; an accidental fire during the first dress rehearsal caused an area of grassy habitat and two small frog ponds to be burnt out.
- a marquee village on the south-eastern edge of the Brickpit rim served as the Sponsor Hospitality centre; an elevated footbridge into this area from the showground site gave expansive views into the Brickpit, and resulted in funding being provided to remove a large quantity of highly visible loose pieces of rubbish and debris (cleared by herpetologists as being of low frog habitat value) from the Brickpit floor.
- a temporary coach parking area was established on the northern edge of the Brickpit; connection of frog underpasses in this area linking the Brickpit and Wentworth Common had been previously postponed until after heavy construction vehicles access for the WRAMS works had finished, and was further postponed until after the Games.

Media and promotion

Frog conservation works received considerable local and international media attention in the lead-up to the Games, resulting in many print and television stories produced in Australia and internationally. The bell frog became an icon for frog conservation and for endangered species conservation generally. Its profile was further raised when it was chosen as the mascot of the Olympic Roads and Traffic Authority and widely used in television advertising campaigns. Media entry to the Brickpit was not permitted during the Games themselves, but bell frogs made popular guest appearances at the media centres during both the Olympic and Paralympic Games.

The frog conservation works were recognised when the project won the 2000 Gold Banksia Award for efforts in frog conservation, after also winning the category of Flora and Fauna Conservation. The frog is still used in promoting conservation post-Olympics, and has made guest appearances at open days, community group meetings, media conferences, industry meetings, and children's television shows.

Frog conservation post-Olympics: 2001 - present

Legislative framework

The Sydney Olympic Park Authority (SOPA) took over management responsibility for Sydney Olympic Park in 2001. *The Sydney Olympic Park Authority Act* 2001 establishes the Authority, and carries on the requirement to apply the Environmental Guidelines and principles of ecologically sustainable development.

Frog habitats are primarily located on lands defined in the Act as 'the Parklands'. The Parklands comprise some 425 ha of the Park, and include estuarine creek systems, bike and walking tracks, mangrove forest, sportsfields, freshwater wetlands, picnic areas, a heritage-listed armament depot, planted naturalistic woodland and grassland, remediated landfills, remnant forest, and playgrounds.

The Act contains provisions requiring the Authority to '*protect and enhance the natural heritage of the Parklands*' (s3(d), s13(c)); '*maintain and improve the Parklands*' (s28(a)), and '*ensure the protection of the environment within the parklands*' (s28(d)). The Act also requires a Plan of Management to be prepared and implemented for the Parklands. The Plan of Management is the principal statutory instrument controlling the use, management and development of the Parklands, and contains strategic and detailed operational guidelines for managing their complex landscapes and diversity of uses. It requires all activities to be conducted in accordance with the SOPA Frog Management Plan, and contains specific provisions relating to use and management of frog habitats.

SOPA Frog Management Plan

The SOPA Frog Management Plan was updated in 2002 to reflect the changed nature of the site – from developmental to operational. The Plan sought to continue to promote the long-term viability of the Sydney Olympic Park Green and Golden Bell Frog population, but with a focus on habitat management needs, rather than construction needs (Table 2). Requirements stemming from the various development consents were also incorporated into the Plan.

The Plan was submitted to the regulatory authority in 2001 and approved in August 2002 with the issue of a Section 95(2) Certificate under the *Threatened Species Conservation Act* 1995. The Certificate replaced previous Licences and provides a defense against prosecution for harm to frogs or frog habitat so long as activities are conducted in accordance with the management plan. A variation to the Certificate was issued in October 2003 to include a small parcel of land on Homebush Bay, transferred to SOPA management.

The Plan categorises the Park as primary, supplementary and non- frog habitat areas, with different management regimes applying to each category. Primary habitats are the areas where bell frog habitat had been specifically conserved or constructed, and are considered most important to promoting the long-term viability of the site's population. Primary habitats comprise the Brickpit, Kronos Hill, Wentworth Common and Narawang Wetland (Figure 2).

Frog management practices detailed in the SOPA Frog Management Plan are incorporated into all management, development and visitation activities within bell frog habitats.

Table 2. Strategies for Green and Golden Bell Frog management at Sydney Olympic Park (SOPA & AMBS 2002).

1. Implement appropriate management actions within each of the bell frog management zones to achieve site-wide objectives.
2. Conserve and enhance overall bell frog habitat within existing primary habitat areas to maintain the three existing bell frog subpopulations.
3. Conserve and enhance bell frog supplementary habitat where practical and consistent with park planning documents.
4. Apply more stringent management measures to Brickpit habitats than other primary habitats, as it is the most secure and established of the three sub-populations, and the site has the fewest conflicting management requirements.
5. Maintain linkages between and within primary habitats to facilitate movement and consequently genetic exchange between breeding sub-populations. Maintain linkages of primary habitat areas with supplementary habitat areas and habitat on neighbouring lands where practical and consistent with the Parklands Plan of Management.
6. Implement landscape management practices sympathetic to conservation goals.
7. Implement management practices necessary to maintain habitat services and functions.
8. Implement best practices in activities and works affecting frogs and frog habitat.

Landscape management

With the exception of the original Brickpit habitats, landscapes containing bell frog habitat are completely fabricated and were originally hand-planted with native grasses, reeds, shrubs and trees. The approximately 200 ha of primary and supplementary frog habitats are better described as oversized gardens than natural plant communities, and they require regular adaptive management to maintain their habitat values, control invading weeds, and maintain presentation standards. The plant communities are still young – many less than six years – and their structure and species balances are still developing.

Landscape contractors have the most extensive day-to-day interaction with frog habitats, and have considerable influence on successful habitat performance. However, normal horticulturalist practices need to be modified for working within frog habitats, and new management actions targeted at ecological objectives need to be applied. 'Best practice' protocols have been developed for Plague Minnow *Gambusia holbrooki* control, slashing of long grass and weeds, herbicide application, noxious and invasive weed management, pond management, and seasonal timing of habitat management works. Ecology induction training is provided to landscape teams working in frog and other threatened species habitats within the Park.

Vegetation Management Plans have been developed for each parkland precinct that contains threatened species or communities; these consolidate legal and policy requirements, and identify habitat outcomes sought and horticultural practices to be applied. Regular habitat inspections are held where SOPA, herpetologists and landscapers review and plan habitat management activities. A cyclic draining program has been developed and implemented over three years for the control of gambusia in Narawang Wetland (O'Meara and Darcovich 2008). New ponds have been installed where existing ponds have developed water retention problems; ponds with fiberglass liners are currently being trialed.

Development

Since the Olympics, development consent has been granted for several park development projects within primary and supplementary frog habitats (e.g. Muir unpublished data). However, the majority of works within frog habitats now involve maintenance and repair, or occur under existing development consents. In particular, the consent for the Millennium Parklands Concept Plan approved a 15-year development program, conditional on mitigative measures detailed in the development application being met and maintained throughout the implementation of the Plan.

The SOPA Frog Management Plan contains protocols to be applied in planning and designing such works and developments, and guidance for contractors conducting these works. They are based on former Licence conditions and ongoing consent conditions, and contain measures to protect individual frogs that may be directly harmed by the works, as well as those that avoid long-term impacts on the frog population. Ecology inductions are provided to contractors undertaking the works, and environmental management plans are required.

Monitoring and reporting

Monitoring of the frog population has been conducted since 1996 (Muir *et al.* 2000; Stokes *et al.* 2006) and continues to be a regulatory requirement and a key input to frog habitat management. The monitoring program is currently conducted by contracted herpetologists, SOPA staff, and members of the NSW Frog and Tadpole Study Group. Reports are provided annually to the regulatory authority; monitoring data are currently being analysed with the intention of publication in the scientific literature (Glenn Muir, Trent Penman, Elizabeth Magarey, Emma Burns, Cate McElroy *pers. comm.*). The site-wide bell frog population was last estimated at over 1500 adult frogs (Magarey *et al.* 2001); with breeding populations continuing to inhabit the Brickpit, Kronos Hill / Wentworth Common, and Narawang Wetland. Calling males have been recorded in wetlands at four other locations in recent years (McElroy *et al.* 2005).

Community and education

The parklands attracted over one million visitors in 2005, and this figure is expected to substantially grow as the parklands and surrounding areas continue to develop. Interpretation, nature-based tours and curriculum-based excursion programs are significant elements of the Park's programs, and explore aspects of the bell frog conservation program, and ecology and conservation generally.

A field-based educational program has been developed for Narawang Wetland; a Licence issued under the *NSW National Parks and Wildlife Act* 1974 conditionally authorises educational programs within some of the habitat ponds, whereas previously public access was excluded, and fencing of all breeding ponds was required.

An aerial walkway, the 'Brickpit Ringwalk', was opened in December 2005 giving Park visitors expansive views into the Brickpit while protecting the bell frogs and their habitat (Fig. 6). The Ringwalk is elevated 18 m above the Brickpit floor, and has a circumference of 550 m. Interpretive material explores the themes of geology, urban ecology, threatened species conservation, water recycling and industrial history.

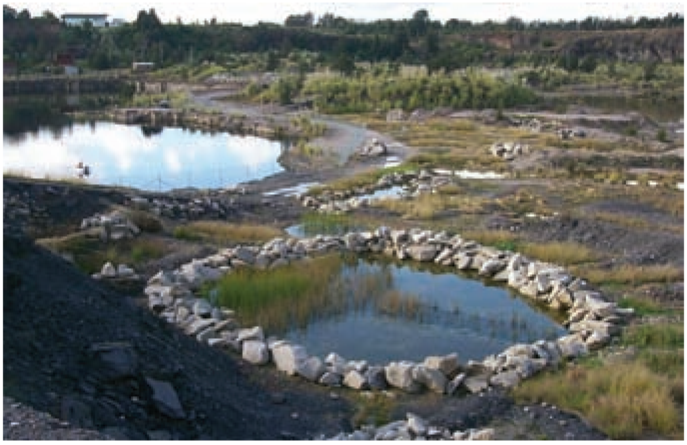

Figure 6. The Brickpit Ringwalk elevates visitors 18 m above frog habitats on the Brickpit floor.

Considerable planning went into delivering the Ringwalk, including designing it so that visitors and habitats would be separated, siting it in the north-west corner of the Brickpit and away from the most ecologically-sensitive wetlands, timing the works to avoid the peak bell frog breeding season, and applying environmental best practices throughout construction. In 2005, the Ringwalk won an Energy Australia - National Trust Heritage Award for heritage conservation and tourism. New educational programs are being developed for the Ringwalk.

Conclusion

The redevelopment of Sydney Olympic Park has occurred concurrently with the successful conservation and enhancement of the Park's Green and Golden Bell Frog population. The combination of regulatory oversight, corporate commitment, funding, and multidisciplinary input by committed scientists, engineers, designers, builders and managers has been integral to this success.

In a full reversal of thinking, the Brickpit habitats that were once intended to be destroyed are now valued and are promoted as a bell frog 'sanctuary' (Fig. 7). Two areas of constructed 'satellite' habitat (Narawang Wetland and Kronos Hill / Wentworth Common) continue to support bell frog breeding populations, and are managed to promote their continued viability.

So far, success can only be measured on a short to medium-term basis – constructed habitats are at the most 10 years old; they have been altered and disturbed by new works throughout this time and are yet to stabilise. The habitats will also become exposed to more and different types of human disturbance as visitation to the Park increases; and the response of this population to high levels of human activity remains to be seen. Habitats outside the Brickpit were originally constructed to mitigate against habitat loss during site redevelopment; these areas will be under pressure to accommodate more uses and facilities as the parklands continue to develop.

this place
is a sanctuary
for the endangered
Green and Golden
Bell Frog

Figure 7. Interpretive signage on the Brickpit Ringwalk identifies the conservation values of the Brickpit.

The need for continued management of both constructed and original Brickpit habitats into the long-term is recognised in corporate policies, and in regulatory approvals and consents. Future challenges include not only how to best maintain and manipulate these habitats for frog conservation, but also how to manage the conservation impacts of increasing visitation and land use pressures.

It is hoped that the insights gained into managing an endangered frog population in a highly modified landscape with on-going development will inform attempts to manage and conserve other bell frog populations and possibly populations of other frog species.

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